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AERIAL THERMAL SCANNER DATA FOR MONITORING ROOFTOP TEMPERATURES

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and

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ABSTRACT

CENGAS, a division of Central Telephone and Utilities Corporation in cooperation with the Remote Sensing Institute, South Dakota State University, is using airborne thermal scanner data to monitor relative rooftop temperatures. Four Nebraska communities and one South Dakota community were surveyed by the Remote Sensing Institute for CENGAS. Thermal scanner data were converted to a film format and the resultant imagery has been successfully employed by CENGAS. The program places emphasis on heat losses resulting from inadequate home insulation, offers CENGAS customers the opportunity to observe a thermogram of their rooftop, and assists homeowners in evaluating insulation needs.

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INTRODUCTION

As energy sources become increasingly scarce and fuel costs persistently rise, those responsible for allocating and conserving energy are investigating methods for reducing energy consumption. An obvious way to conserve is to reduce the quantities of wasted energy. Since a great amount of our energy requirements are in the form of heat to keep indoor areas comfortable, an important source of wasted energy is building heat loss.

A December, 1974 report by the Government Operations Committee of the U.S. House of Representatives gives the U.S. only five years to halve its rate of increase in energy consumption; otherwise, the committee reports, the quality of life in this country will begin to erode. The study places emphasis upon conservation of energy. The guideline suggested in the report is to reduce the rate of growth of our energy consumption from 4.5 percent to two percent annually. The report declares that, for builders to get federal loans, their designs must include far more insulation than has been the case in the past. Even older homes, the report continues, being improved with federal loans, should have their insulation upgraded. The Federal Energy Administration estimates that a 25 percent tax credit for such purchases as insulation for unfinished attics and storm windows and doors could reduce the country's daily oil consumption by 50,000 to 100,000 barrels.

According to the Government Operations Committee report, 20 percent of our total energy is consumed in private homes and apartments, over half of it for heating. Heat loss studies of structures have shown that a high percentage of the lost heat passes into the attic and out through the roof. Under such conditions, variations of roof temperature would be expected. Presently, few people are aware of the adequacy or condition of their insulation. A city-wide program for determining structures that are wasting energy and in need of additional insulation would be extremely time consuming to conduct by conventional methods. A rapid method is needed to initially measure, in a qualitative manner, energy losses from homes and businesses. The Remote Sensing Institute (RSI) at South Dakota State Univeristy, Brookings, South Dakota has developed a Daedalus aerial thermal scanning system to survey entire

communities for apparent rooftop temperatures.

PROCEDURE

An operational rooftop temperature monitoring program was conducted by RSI for CENGAS, the Gas Energy Division of Central Telephone and Utilities Corporation, Lincoln, Nebraska, during the winter of 1975. Five upper-midwestern communities were surveyed at an altitude of 488m (1600 ft) above ground. Each flight line provided coverage over a strip approximately 3 city blocks wide. A detailed flightline map was prepared for each city, and optimum locations for directional lights determined. A CENGAS crew, in communication with the RSI aircraft, was employed to set directional flashing lights to assist the aircraft in flying the predetermined flight lines. Figure 1 is an example of the map used by the aircraft and ground crews during the data acquisition. The ground crew marked each vehicle location prior to the flight and rehearsed their activities prior to the actual flyover.

Thermal scanner data were recorded on magnetic tape and laboratory processed to a 70mm continuous film base format. Laboratory analysis, including level slicing of data, produced optimum contrast in gray levels for a majority of the residential roofs. The film data prepared by RSI were printed for CENGAS by the University of Nebraska Remote Sensing Center on black and white photographic paper. The CENGAS division offices catalogued the prints as to flight line number and the flight maps were used for rapid accession to the proper thermogram print.

CENGAS is using the data in a public service type program to show individual homeowners relative conditions that indicate the effectiveness of roof insulation in conserving energy. Multi-media advertising is informing the public that such imagery is available for interested homeowners to inspect at local CENGAS offices. Trained CENGAS employees are present to assist in the interpretation of the data.

The flyover operations, data acquisition, data processing, advertising and promotion were planned centrally by the corporate staff and representatives of the three CENGAS divisions. They include the Nebraska Division which operates in 54 towns in the eastern third of the state, the Lincoln Division which includes Lincoln and two other towns, and the South Dakota Division which is in Sioux Falls and 12 other towns.

Procedures for using the data were developed individually by each division. All three divisions used the method of inserting an invitation with the customer's monthly billing statement to visit or call for an appointment to see their thermogram. Interpretation of the data was made by the customer, together with the CENGAS representative, in a special location in the company's local office buildings. Displays were used to complement the interpretation process and are illustrated in Figures 2 through 5. The South Dakota Division's initial approach was more detailed and individualized than the other two divisions. It was designed to provide participating customers an individualized economic analysis of adding ceiling insulation. The cost of adding insulation to standard levels was calculated and compared to the projected annual savings in fuel bills. It became apparent from the early respondents that this service was not necessary in many cases. Most customers wished only to review the thermogram. All divisions seem to be evolving toward general similarity in their procedures.

RESULTS

Date and time of data collection, general weather conditions and the general quality of the data for the five communities are found in Table I. The data for Beatrice and Lincoln were of equally good quality and the best of the data sets collected.

Columbus data contained more moderate contrasts. The reduction in contrast on the Columbus data is attributed to the moderate haze and humidity conditions at flight time. Norfolk was the last of the cities to be flown (mid-April) and surface temperatures during the day were approaching +15.6° C (60° F). It is possible that the heating effects of the warm day were not reduced sufficiently at flight time, i.e., roofs heated by solar energy had not radiated the absorbed energy back into the atmosphere. In addition the surface temperature during the complete data collection mission was above freezing. The Sioux Falls data was poorest of the five surveyed communities. Areas of expected high temperature contrasts revealed little or no distinction on the data. Overall temperature contrasts were poor. The temperature spread between surface and air temperatures was not appreciably different than for other flights. However, the surface temperature at Sioux Falls

TABLE I. FLIGHT DATA

City	1970 Census	Flight Date	Take-off Time	Cloud Condition	Haze Condition	Temperature (°C/°F) at Altitude	at Surface	Data Quality
Beatrice	12,389	2-26-75	2311	Clear	Light	-2/28	-3.3/26	Very Good
Lincoln	149,518	2-28-75	0026	Clear	Light	0/32	0/32	Very Good
Lincoln		3-1-75	2236	Clear	Light	-8/18	-4/25	Very Good
Columbus	15,471	3-3-75	0017	Clear	Moderate	-12/10	-10/14	Good
Sioux Falls	72,488	3-19-75	2358	Clear	Light	-2/28	+2.2/36	Adequate
Norfolk	16,607	4-12-75	2215	Clear	Light	0/32	+1.1/34	Adequate

was above freezing, varying between 1.1 and 2.2° C (34 and 36° F) . throughout the mission. For Norfolk and Sioux Falls it is theorized that the lack of data contrasts is a result of the relatively warm (greater than 0° C (32° F)) surface temperatures present during data collection and the relatively high temperature during the day previous to the night-time flight.

From these data, optimum flight conditions might be theorized as clear skies, a maximum of light haze conditions, snow-free rooftops, surface temperatures equal to or less than 0° C (32° F), absence of a temperature inversion, reasonable dew point spread, and calm winds. Flight timing should vary with the specific weather conditions, but should be as late as possible to allow for completion of the mission before dew or frost appears.

DISCUSSION

The communities surveyed and respective program information as of September 19, 1975, are listed in Table II.

While thermal data was of varying quality, see Table I, the results, in terms of average number of visitors per gas customer per day appears to be fairly consistent. As can be seen in Table II, the values are in the general range of .001 to .003. Also consistent was the rate at which insulation was being recommended from interpreting the thermograms with homeowners. CENGAS personnel estimate that of the customers talked to in the surveyed communities, no less than 60 percent could cost-effectively benefit from added insulation. It was also observed that very seldom did the owner of a non-insulated home respond to the invitation to view their thermogram. Therefore, it is estimated that if a statistical sample of the houses was evaluated, the cost-effective percentage would be increased. In addition to the 7400 visitors listed in Table II, Lincoln recorded some 3800 telephone calls regarding the data. In some cases, the individual or agency personnel viewing the thermogram were inspecting more than one building, so CENGAS officials estimate 8400 structures in the Lincoln area have been evaluated, and 17,000 evaluated in the total survey area.

Figure 6 is a copy of a letter received by CENGAS from a large insurance company in Lincoln. After viewing the thermogram of their

TABLE II. CENGAS THERMOGRAM PROJECT INFORMATION*

City	1970 Census	No. Gas Customers	Date Program Started	Total No. Visitors	Percent of Customers Responding to Date	Average No. Visitors/ Customer/day	Estimated Percent Visitors Requiring Improvement in Home
Beatrice	12,389	5,200	June 1	1,900	36.5	.003	90
Lincoln	149,518	54,900	June 1	7,400	13.5	.001	60
Columbus	15,471	5,700	June 15	1,600	28.1	.003	60
Sioux Falls	72,489	24,600	June 1	1,900	7.7	.001	70
Norfolk	16,607	6,200	July 1	1,400	22.6	.003	60

*As of September 19, 1975

building, Figure 7, company officials discovered areas where leaking roofs resulted in moisture damage to insulation. At least 20 other Lincoln businesses have viewed their thermograms. In each case the business obtained basic information from the CENGAS thermogram and have improved or are in the process of improving their buildings in line with conservation objectives. The normal commercial customer comment is that the remote sensing data aided in detecting moisture-damaged insulation resulting from roof leaks. Two conservation-minded companies in Lincoln have allowed their employees to take time off from work and provided transportation to the Lincoln CENGAS offices so their employees could view their thermograms.

Surveys of local and state-owned buildings in Lincoln have indicated that many government buildings are in need of inspection. Figure 8a is a photo representing a Lincoln school as "seen" by the thermal scanner. The figure shows what appears to be several separate buildings. The thermogram is actually that of a single building. The connecting hallways are appearing much warmer than the adjacent rooms. Figure 8b is the same grade school building but level sliced and printed for analysis of the non-hallway roof area. The warmer areas were investigated and it was determined that water damage had caused considerable reduction in insulation ability. The Lincoln school system has obtained a thermogram for every building in the system and is evaluating them for roof damage and insulation characteristics. One high school has already been renovated and new insulation is being installed.

The city of Lincoln is operating a similar program for all city owned buildings. The state of Nebraska has one man employed full time in on-site analysis of thermograms of all state-owned buildings in Lincoln and other surveyed towns. Preliminary information prepared by CENGAS indicate that at least 20,000 Lincoln homes may need more insulation. Studies indicate that insulation in the attic of a home to insulation R-19 level could result in an annual savings of 49 million BTU or $73 per home, based on current gas rates. Additional savings could be realized for air conditioned-homes. Insulation contractors in the Lincoln area are estimating at least a 20 percent increase in business in 1975 compared to 1974. In addition, lumber dealers are reporting a 25-30 percent

increase in insulation sales to do-it-yourself type customers.

The thermogram print of Figure 9 shows two of seven buildings owned by a Sioux Falls man. In all seven cases, the thermogram interpretation of insulation characteristics coincided with what the owner expected from his knowledge of the property. The Sioux Falls CENGAS office conducted a survey of 278 thermogram customers. Of the 66 percent returned questionnaires, 35 percent indicated they intended to conduct corrective measures to reduce potential heat loss from their homes. The reaction seems similar in the other four towns. Insulation companies report increased interest in home insulation reflected by increased sales. Although no precise figures are available for Sioux Falls, many individuals are making telephone inquiries to insulation contractors based on thermogram viewing.

In Columbus, insulation companies reported 83 homes insulated since the CENGAS program began. All 83 of the homeowners had viewed the thermogram of their homes at the CENGAS office. When one Columbus man viewed his home on the thermogram, it appeared quite warm. Wondering if this was reflective of his high heating costs, he looked into the attic of the recently purchased 10-year old home and discovered the building was completely uninsulated.

The overriding comment made by CENGAS thermogram interpreters was that in a high percentage of the cases they definitely can tell the difference between well-insulated buildings and those with very little insulation and determine inferences for those with insulation characteristics not so extreme. Some customers are expressing initial skepticism on the accuracy of the data interpreted from a thermogram but this doubt is generally eliminated as the interpreter points out such features as back porches, chimneys, parked cars, garages, driveways and sidewalks. The interpreter's ability to evaluate insulation characteristics via the thermogram can be enhanced in two important ways: 1) the interpreter should be knowledgable in home insulation (although not a strict requirement) and 2) the structure owner should be present during the interpretation process. The personal approach to the thermogram interpretation allows for a more precise visual analysis. For example, in situations where the thermogram indicated poor insulation, and the homeowner said

the insulation was good, further discussions during the interpretation procedure generally revealed exceptions such as attic furnaces, attic duct work, or, in some cases, incorrectly installed insulation. In Sioux Falls, where data contrast was not optimal, construction materials and styles also seemed to affect the interpreted results. Pitch and gravel roofs, A-frame homes and story and-a-half homes occassionally contradicted the basic premise that insulation was the dominant factor influencing apparent roof top temperatures. CENGAS interpreters report that the incidence of gross misinterpretation is very low and has caused no problem in customer public relations. In fact, in the few cases where gross misinterpretations did occur, it was generally the case of a well-insulated home interpreted as inadequate. In any case, the thermogram has helped to point out problem areas in home heating and insulating procedures.

SUMMARY

As far as is known by RSI and CENGAS officials, this is the first time a thermal scanner has been used in an operational program of this type and magnitude. CENGAS officials are extremely pleased with the results of the program. They feel it illustrates the effectiveness of such a procedure for surveying large areas for possible heat loss and dramatically focuses public attention on the need for energy conservation. Such data might assist energy-conscious agencies, both private and governmental, in more effectively guiding their energy conservation efforts and in providing information for public awareness programs.

ACKNOWLEDGEMENTS

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South Dakota State University
Brookings, South Dakota 57006

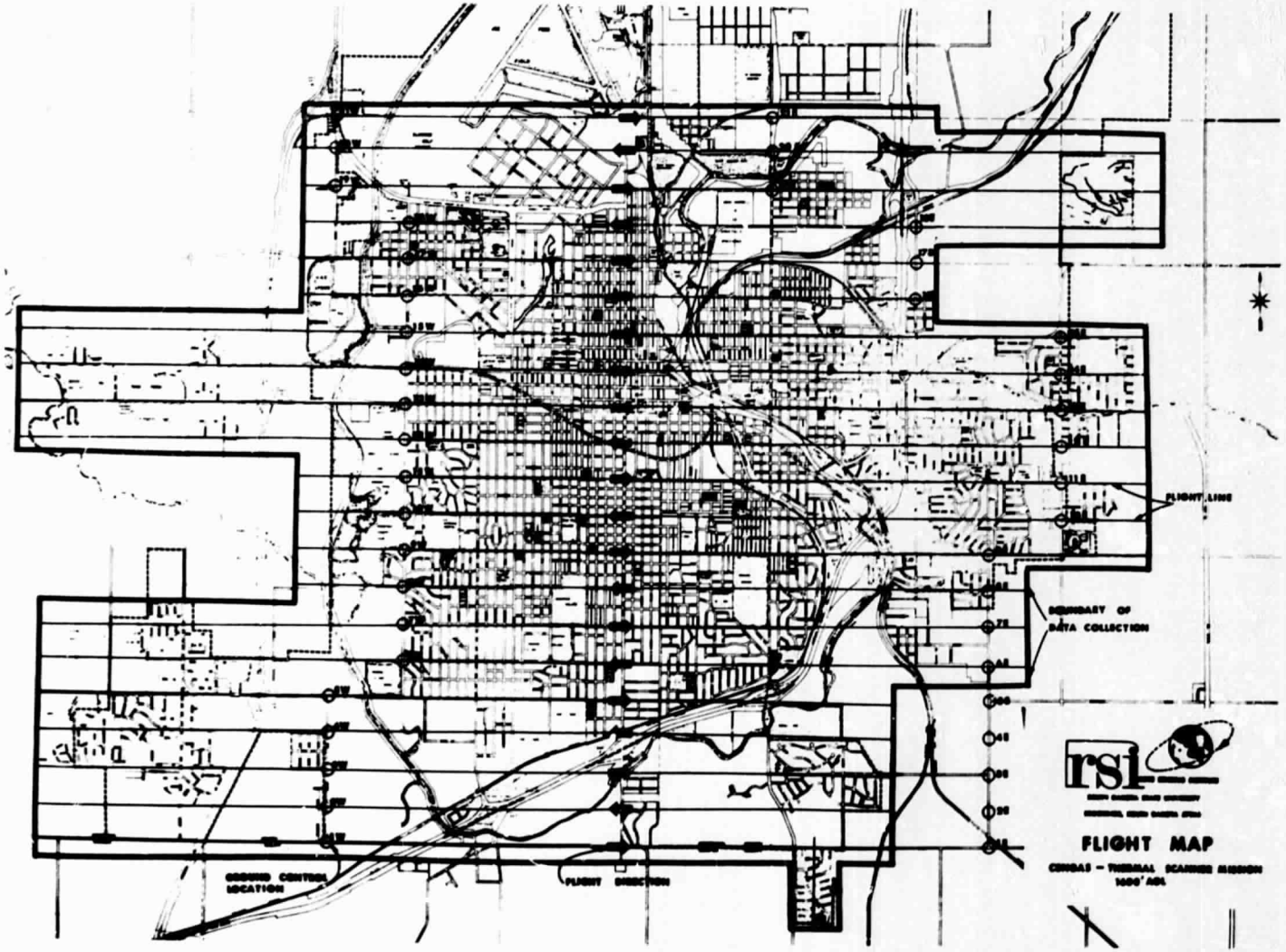

Figure 1. Flight line map used by aircraft and ground crew for data collection in Sioux Falls, South Dakota.

Figure 2. Portion of lobby display in CENGAS office at Lincoln, Nebraska.

Figure 3. Location map used by CENGAS interpreters to locate thermogram print of customer building.

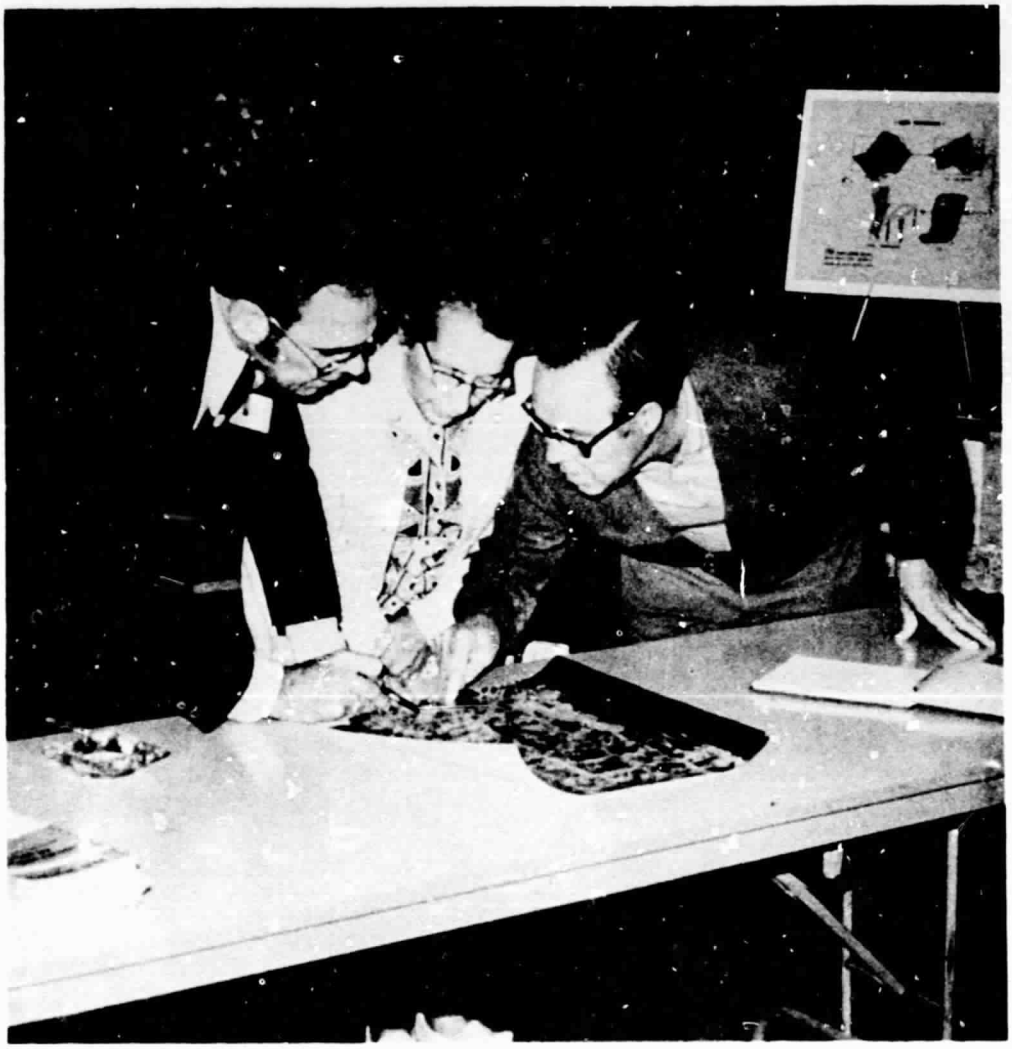

Figure 4. CENGAS employee discussing thermogram with customers.

Figure 5. CENGAS customer evaluating insulation display after viewing his thermogram.

BANKERS LIFE NEBRASKA

W. D. MARTING
Secretary

September 11, 1975

Mr. Clancy Woolman
Division Marketing Manager
Central Telephone & Utilities
1201 N Street
Lincoln, Nebraska

Dear Clancy:

You may be interested to know that we have used the thermogram that you graciously provided to evaluate our heat loss problems and a decision has now been made to reroof the entire main addition of the building.

We wish to thank you once again for your fine cooperation.

Sincerely,

Bill

W. D. Marting

WDM:dk

HOME OFFICE: LINCOLN, NEBRASKA 68501

Figure 6. Bankers Life Nebraska letter providing documentation of their use of thermogram print.

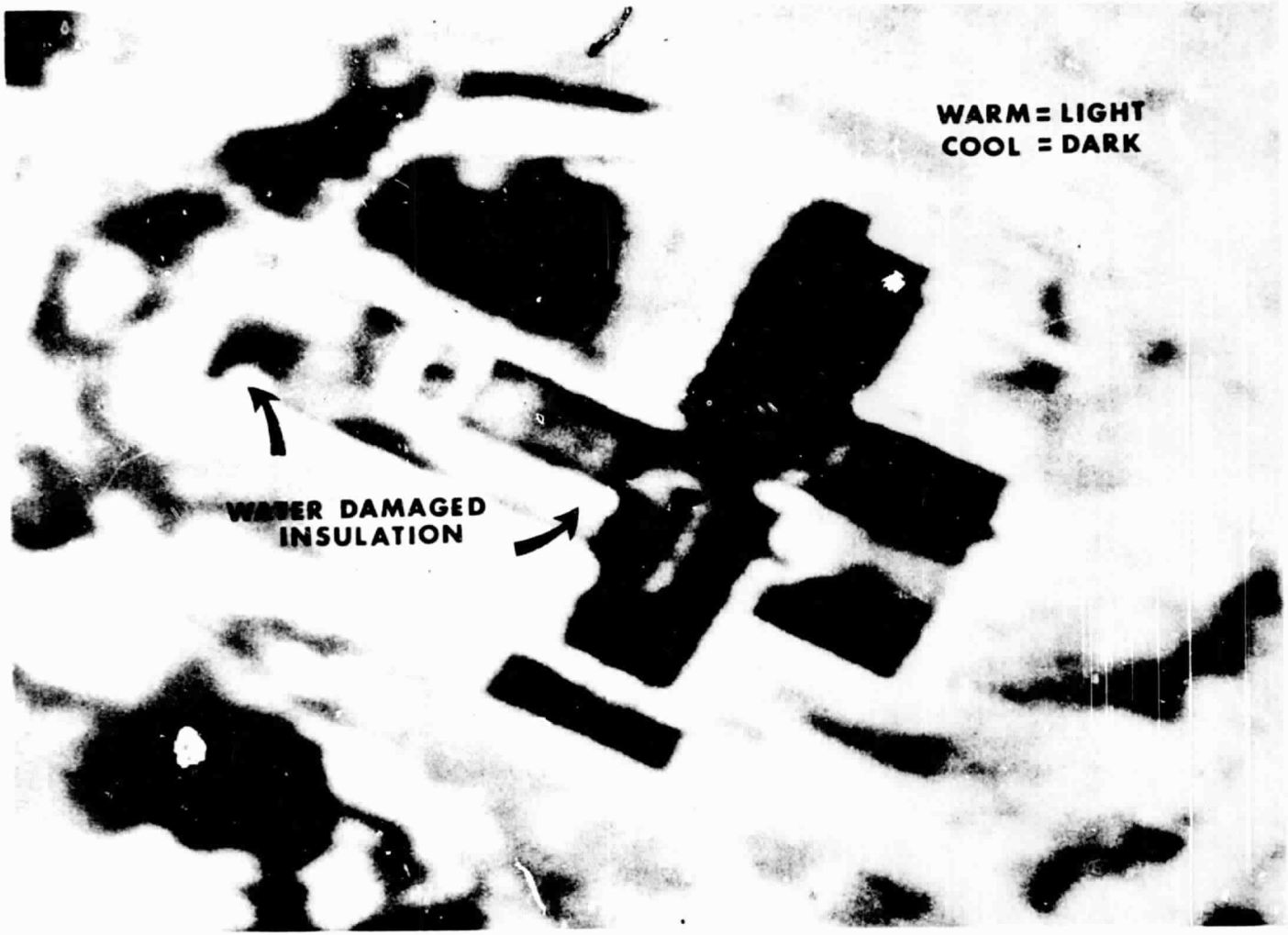

Figure 7. Thermogram of Bankers Life Insurance Building, Lincoln Nebraska, processed to show the differences in apparent roof temperature that were verified as water damage to the roof structure.

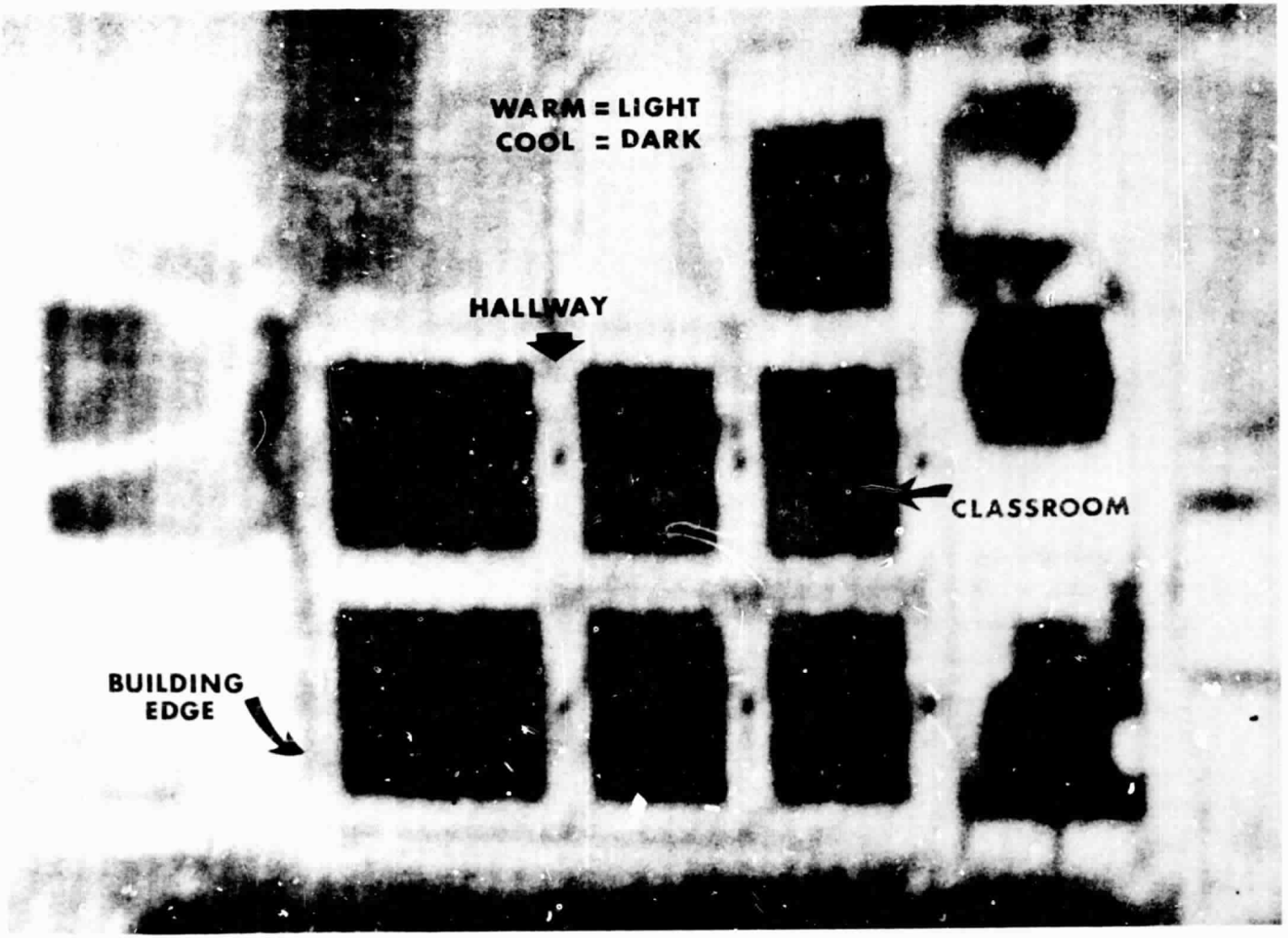

Figure 8a. Thermogram of Arnold Elementary School, Lincoln, Nebraska, processed to illustrate the differences in roof temperature between the hallways and the classrooms.

Figure 8b. Same building as Figure 8a but processed to show differences in temperature that were verified as water damage to insulation.

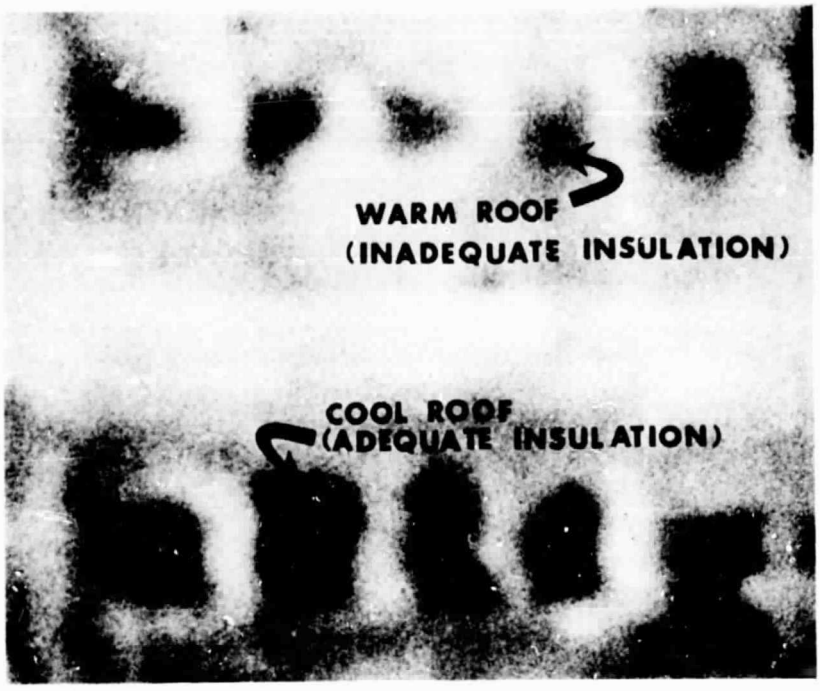

Figure 9. Residential area of Sioux Falls, South Dakota. Thermogram shows two homes with the interpretation and owner's verification of the insulation in each.

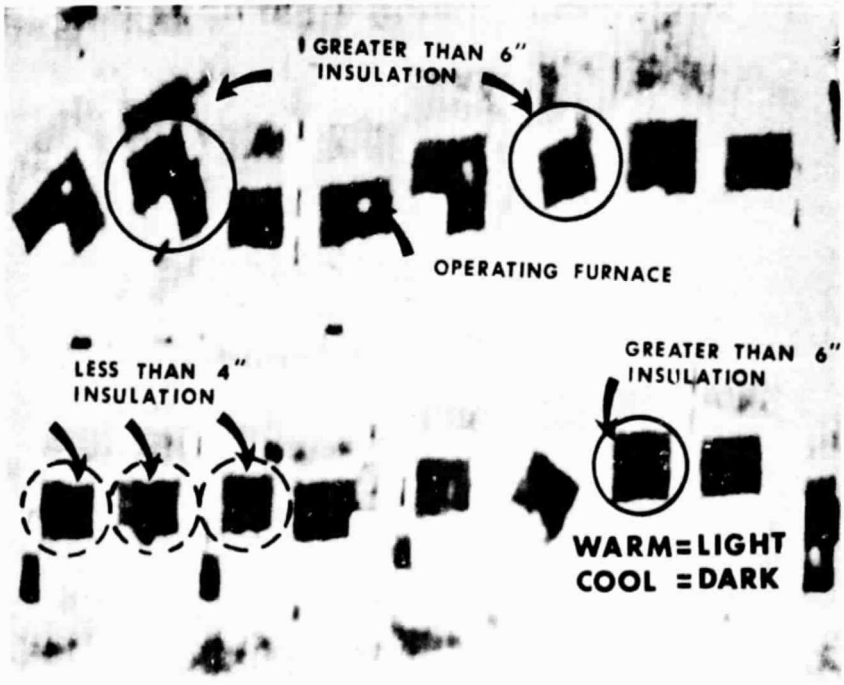

Figure 10. Thermogram of newer homes. Contractor of circled homes provided insulation data. Notice well insulated rooftops appear cooler than those homes with less insulation.